



SENSORS AND LIGHTWEIGHT INSTRUMENTS FOR VENUS ATMOSPHERIC INVESTIGATIONS

Gary W. Hunter, Ph.D.
Intelligent Systems Hardware Lead
Sensors And Electronics Branch
NASA Glenn Research Center
Cleveland, OH



BRIEF SCIENCE OVERVIEW





Example Proposed Instrumentation for Atmosphere Studies

Table 4.9: Balloon Instruments.

Instrument	Mass (kg)	Power (W)	Source or Proxy
Gas Chromatograph Mass Spectrometer	11	40	Next-gen Huygens, JPL VCAM
Thermocouple, Anemometer, Pressure Transducer, Accelerometer	2	3.2	MVACS, ATMIS
Radio Tracking	0	0	–
Net Flux Radiometer	2.3	4.6	Galileo Probe
Magnetometer	1	2	JPL internal studies
Nephelometer	0.5	1.2	Pioneer Venus
Lighting Detector	0.5	0.5	FAST
TOTAL	17.3	51.5	

Venus STDT Section 4.3.2



Scientific Objectives for the Exploration of Venus by Aircraft Venus STDT Section B2.1

- The determination of atmospheric properties over a region of the atmosphere.
- Direct sampling and analysis of the atmosphere.
- Characterization of trace gasses as possible biogenic indicators of life.
- Searching for volcanic emissions in specified regions of the planet.
- Magnetic field mapping over a region of the planet.
- Platform for radar investigations of the surface.
- Magneto-telluric sounding of the interior.
- Correlation of atmospheric motion between different locations by two or more aircraft.
- Communications and command relay for balloons, landers, and possible surface vehicles.



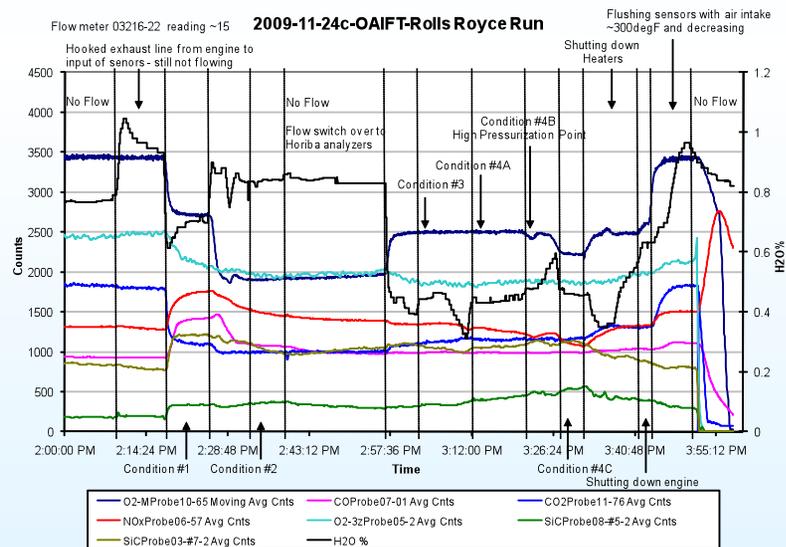
OVERVIEW

- **FLIGHT CONDITIONS SIMILAR TO THAT OF EARTH FLIGHT MISSION EXCEPT:**
 - **HIGH WINDS**
 - **SULFUR CONTENT**
- **COMPLEX AND LARGER INSTRUMENTATION EXISTS**
 - **HIGH CAPABILITY SYSTEMS**
 - **IMPLEMENTATION MAY BE CHALLENGING DEPENDING ON THE ATMOSPHERIC FLIGHT PLATFORM USED**
- **SIGNIFICANT AMOUNT OF TERRESTRIAL ATMOSPHERIC SCIENCE EXPLORATION ON-GOING; DECREASE IN SIZE, WEIGHT, AND POWER ON-GOING**
- **THIS PRESENTATION GIVES A BRIEF OVERVIEW OF SMALLER, LIGHTWEIGHT SYSTEM'S THAT MIGHT BE USED FOR VENUS ATMOSPHERIC INVESTIGATIONS**
 - **TARGETED TOWARD SCIENCE OBJECTIVES**
 - **CORE SUGGESTION: SMALLER SYSTEMS MAY ADDRESS ASPECTS OF SCIENTIFIC QUESTIONS WHILE BEING MORE APPROPRIATE FOR SOME AERIAL PLATFORMS**
 - **IN EACH CASE, MODIFICATION FOR VENUS ENVIRONMENTS NEEDED**

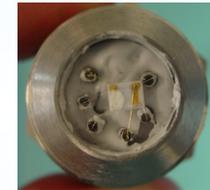


MEMS GAS SENSOR ARRAY

- **PLACEMENT OF SENSORS SIGNIFICANTLY CLOSER TO THE ENGINE OUTLET THAN TRADITIONAL EQUIPMENT ALLOW REPLACEMENT OF INSTRUMENT RACKS**
- **PROVIDE MEASUREMENTS IN APPLICATIONS WHERE SYSTEMS SUCH AS MASS SPECTROMETERS WOULD BE PROBLEMATIC**
- **PRESENT WORK INCLUDE MEASURING ENGINE EMISSIONS FOR DETERMINATION OF ENGINE HEALTH**



Packaged Sensor



Sensor Array Engine Data At Rolls-Royce

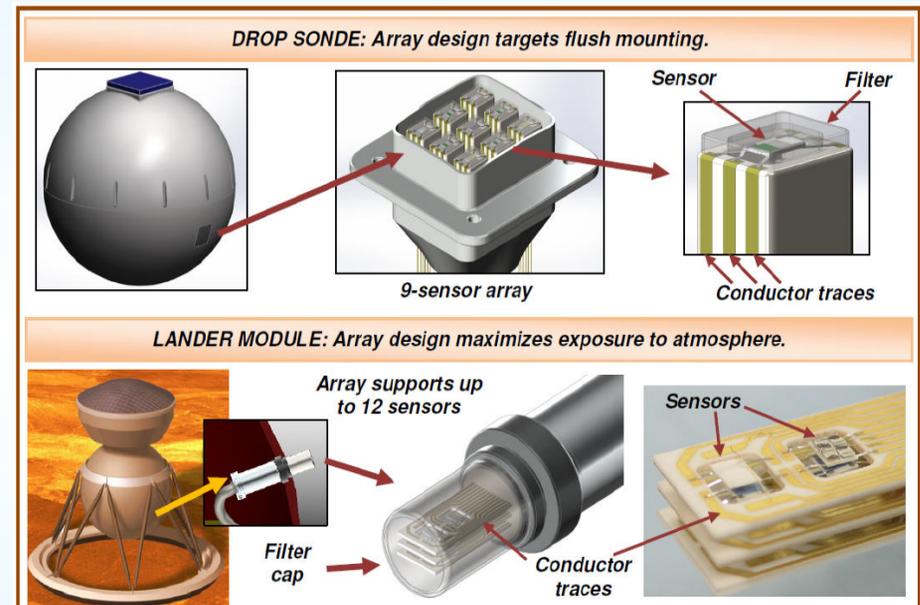
Rake Sampling System At The Outlet Of The JT-12 Jet Engine.



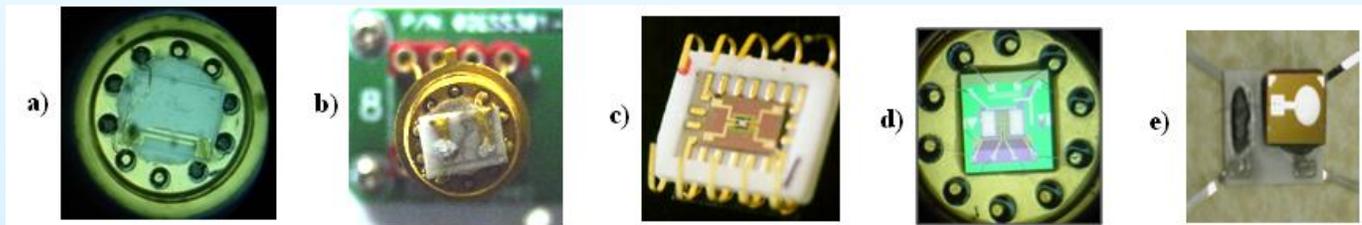


VENUS APPLICATION DEVELOPMENT Phase I SBIR

- LEVERAGE MEMS-BASED SENSOR DEVELOPMENT FOR VENUS APPLICATIONS
- OPERATIONAL OVER A BROAD RANGE OF APPLICATION ENVIRONMENTS
- TARGETED TOWARD DROP SONDE APPLICATIONS FOR BOTH ATMOSPHERIC AND SURFACE MEASUREMENTS
 - PROFILING CHEMICAL COMPOSITION OF THE VENUS ATMOSPHERE IN A DROP SONDE
 - PROVIDING GAS COMPOSITION MEASUREMENTS AS PART OF THE LONG LIVED LANDER WITH METEOROLOGICAL MONITORS.



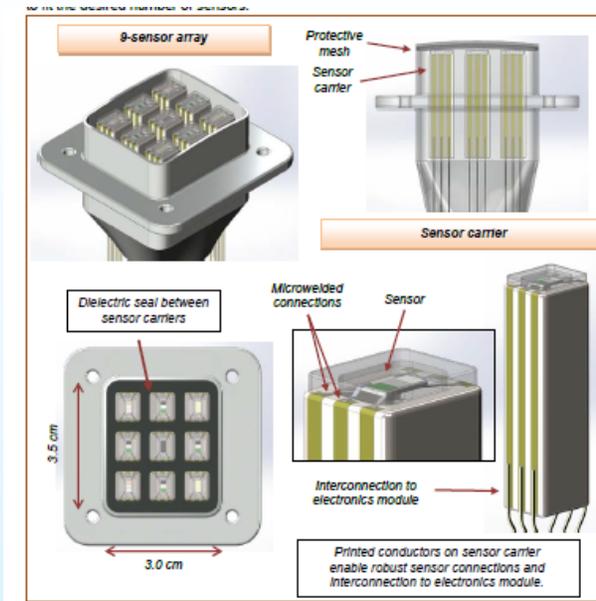
Examples of packaged MEMS based sensors





VENUS SCIENCE APPLICATION

- FOR APPLICATION RANGES WHERE MORE COMPLEX INSTRUMENTS ARE CHALLENGED BY SIZE OR WEIGHT CONSIDERATIONS
- COULD BE COUPLED WITH A DROP SONDE TO COMBINE MONITORING OF SPECIES AT HIGHER ATMOSPHERES WITH A PROFILE DOWN TO THE SURFACE
- A RANGE OF SPECIES OF INTEREST HAVE BEEN IDENTIFIED
 - MULTIPLE SENSOR DESIGNS TESTED
 - MOST MATURE SYSTEMS NO, CO, O2, H2O, H2 AND SOx
 - DESIGNS FOR OTHER SPECIES INVESTIGATED
 - ARRAY AIMED TOWARDS A SMALLER FOOTPRINT THAN MORE COMPLEX SYSTEMS
 - 8 TO 12 SENSOR ARRAY: ~200 gm , 4 cm X 4 cm X 4 cm, ~ 1 W



Species	Measurement Range of Interest	Tested in Phase I
CO	0-50	Yes
SOx	0-200	Yes
OCS	0-50	Yes
H2	0-30	Yes
HF	0-50	No
HCl	0-5	No
NO	0-30	Yes
O2	0-50	Yes
H2O	0-100	Yes



MINIATURIZED PARTICULATE SENSOR

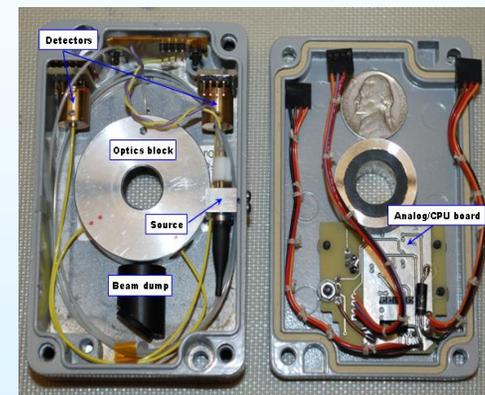
- **PRINCIPAL ELEMENT: MONOBLOC OPTICAL ASSEMBLY HOUSING TRANSMITTING AND RECEIVING OPTICS**
- **APPROACH HERE UTILIZES MULTIPLE, FIXED-ANGLE SCATTERING MEASUREMENTS**
 - **ALLOW DETERMINATION OF MULTIPLE DISTRIBUTION PARAMETERS**
 - **FLIGHT QUALIFIED/FLOWN ON ISS**
 - **TOOLKIT OF TECHNOLOGIES FOR A WIDE RANGE OF PARTICULATE SIZES/SHAPES**
 - **MOVING TOWARDS UAV IMPLEMENTATION**

VENUS SCIENCE APPLICATIONS

DIRECT SAMPLING AND ANALYSIS OF THE ATMOSPHERE INCLUDING MEASURING, CHARACTERIZING, AND MONITORING ATMOSPHERIC PARTICULATES IN REAL TIME. RECOGNIZES THE SPECIFIC PROPERTIES OF AN UNKNOWN AEROSOL AND MEASURES THE TOTAL MASS AND SURFACE AREA OF A GIVEN AEROSOL CLOUD .



**MULTIPARAMETER AEROSOL
SCANNING SENSOR**

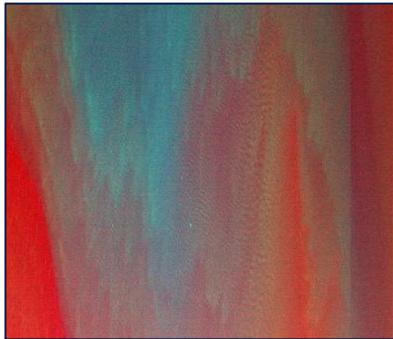


**OPTICAL PARTICULATE SENSOR
PACKAGE**



Airborne Hyperspectral Imager

Designed for Aircraft Implementaiton



Processed HSI data of **Microcystis Bloom** with higher concentrations indicated by red and sediment is in blue (0.8 km x 1.4 km)

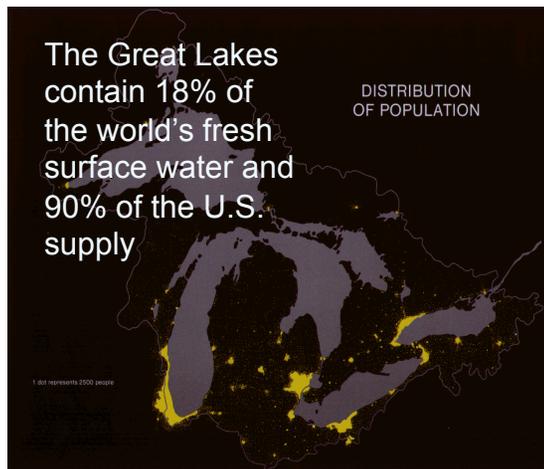
- Great Lakes Ecology: Monitoring Harmful Algal Blooms (HABs) in fresh water ecosystems – **Great Lakes Environmental Research Lab**
- Ecological change: Monitoring change of dry forest and coral reef ecosystems – **University of Puerto Rico at Mayaguez**
- Invasive Species: Measure the spread of invasive plant species in the Detroit River International Refuge – **Eastern Michigan University**

Fundamental Research: 2006 - 2011

GRC and GLERL have demonstrated HSI capable of detecting HABs in low concentrations - key capability for bloom prediction

Venus Science Application:

When included with an upward looking irradiance sensor, it is possible to determine localized atmospheric constituents by measuring spectral reflection and absorption of atmospheric and surface features



<http://www.glerl.noaa.gov/res/Centers/HumanHealth/>





Cloud and Earth's Radiant Energy System (CERES)

- Researchers from GRC and LaRC are working together on CERES follow-on sensors
- Multiple new technologies are being developed and tested for future missions, with a focus towards high yield sensor technologies
- Sensor is measuring total radiance in a band from 400 nm to 100 microns.
- Additional sensors could be included for measuring specific wavelength bands.

VENUS SCIENCE APPLICATIONS

- Instruments very similar to those presently flown to measure the Earth's Radiation budget could be included in a Venus high altitude platform to determine radiant energy contributions from the lower atmosphere and surface. This would also allow for the study of the upper atmosphere contributions when studied concurrently with an orbiter.
- Sensors would be tailored to operation in the Venus upper atmosphere

